Imitation and Innovation Driven Development under Imperfect Intellectual Property Rights☆

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Abstract

Developing countries employ about two fifth of the world's researchers, originate one quarter of world expenditures on R&D, and their inventions are subject to imitation. Nevertheless, the previous literature focuses on North-South setups in which the South is restricted to imitating northern inventions. To analyze the effects of IPR policies on developed and developing countries we extend this literature to allow not only for southern R&D and imitation of northern goods, but also imitation targeted at southern innovations. We find the effects of IPRs on R&D and welfare to be non-monotonic and dependent on R&D efficiency and an innovation threshold in the South. For sufficiently strong IPRs the South engages in R&D and stronger IPRs promote southern R&D, welfare, and a reduction in the North-South wage gap. Below the R&D threshold a strengthening of IPR protection fails to promote R&D and decreases welfare and wages. Stronger IPRs exclusively for southern firms can benefit both regions by shifting southern resources from the imitation of northern goods to original southern innovation.

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JEL: F43, F55, 031, 034

1. Introduction

The distribution of R&D efforts between developed and developing countries is changing. In its Science, Technology and Industry Outlook, the OECD (2008) reports that the distribution of Gross domestic expenditure on R&D (GERD) shifts towards non-OECD countries whose share in global R&D increased from less than 12% to over 18% from 1996 to 2005. A similar pattern arises for business R&D expenditures of profit-oriented enterprises. In China, South Africa, Russia and India, the ratios of R&D expenditure to GDP exceed those of high income countries like Greece and Portugal. UIS (2009)[2] reports an even higher share of developing countries in world R&D for 2007: developing countries accounted for almost 24% of world GERD and employed almost 38% of world researchers. The extent of investments in R&D is closely correlated with the level of domestic IPR protection. Figure 1 plots the Gross expenditures on R&D and GDP per capita against the Ginarte and Park IPR index in 2005.[3]

For the group of countries associated with low levels of IPRs (below an index of about 3), R&D expenditures are below 1% with low variations. Above the threshold, there is a clear positive correlation between R&D efforts, the level of IPRs and GDP per capita.[4] Not only do the graphs show that there is a threshold level of IPRs which has to be reached for IPRs being positively associated with R&D, but also that IPR protection is positively related to income in a country only if it supports a sufficiently developed R&D sector.[5]

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[2]The UNESCO Institute for Statistics.

[3]Data sources: R&D expenditures for 2007 from UIS (2009), IPR index for 2005 from Park (2008a), GDP per capita for 2007 and country codes are from United Nations Statistics Division: National Accounts. We thank Walter Park for sharing the data on the IPR index.

[4]For earlier periods, i.e. before TRIPS was established, the plot looks qualitatively similar, but the data are somewhat shifted to the left, i.e. to lower levels of IPRs. See Park (2008a) for the sources of changes in the index. The same observation is made in Ginarte and Park (1997) who find that high income countries provide the highest level of IPR protection.

[5]That there is also a threshold level also for IPRs and growth which is dependent on the level of human capital in a country is shown by Mohtadi and Ruediger (2010) using a threshold estimation technique.
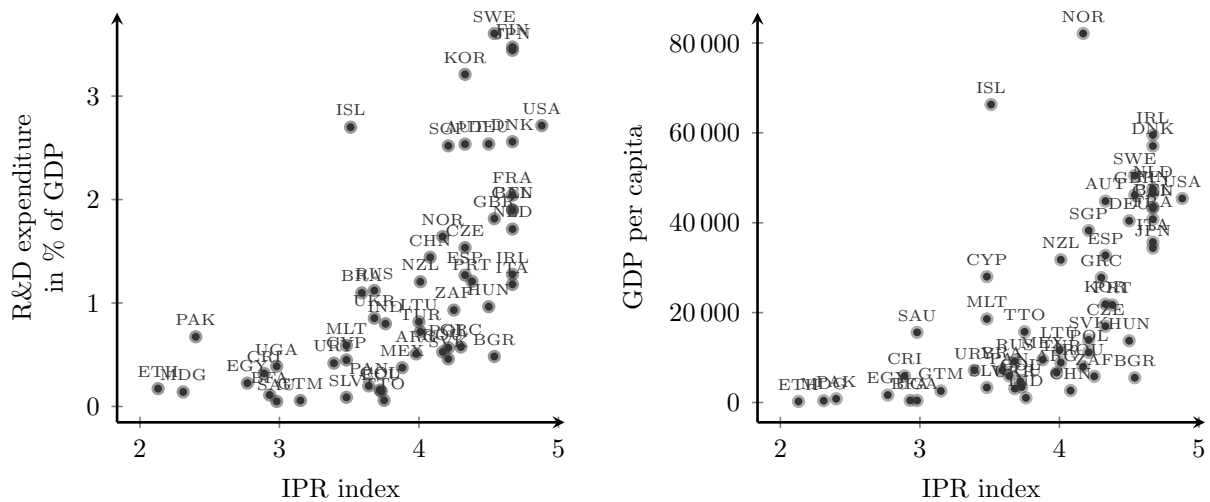
Figure 1: R&D expenditures (GERD), IPRs, and GDP per capita

The division of countries into industrialized innovating countries (the North) and imitating developing countries (the South) in the theoretical literature does not account for the increasing investments in R&D in developing economies shown by these recent surveys[6] and does not allow for scenarios of a transition of imitator countries to successful innovators as demonstrated by Asian Growth miracles like South Korea, Taiwan and earlier Japan.

In this paper, we develop a North-South increasing variety model which allows for original innovation in both the North and the South, and also for the imitation of both northern and southern inventions. We show that our model can explain the IPR-R&D threshold level shown in figure 1, and determine the conditions under which IPRs can stimulate southern innovative activity and increase welfare. We then use the model to analyze the effects of different IPR policies in the South. For the policy analysis the aspect of southern firms being also subject to imitation has two main advantages: First, it allows us to analyze the

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effects of stronger IPRs on southern R&D incentives directly. Second, we can thus examine the effects of IPRs protecting northern or southern goods separately.

While international treaties as the Paris and Berne Convention prescribe the national treatment principle, i.e. equally strong protection for domestic and foreign innovations, this principle might not be followed by developing countries. For instance, as Kumar (2003) describes for the case of Japan until the 1970s, IPR legislation might be in place to unilaterally advance domestic technology adoption from abroad. Thus the second contribution of this paper is to analyze the effects of discriminatory southern IPR policies on both regions.

We find that southern R&D takes place if IPRs surpass a critical threshold level. This critical level is lower for higher southern research efficiency and a larger southern population. This implies that large countries with efficient R&D sectors are likely to engage in innovation even under weak IPR regimes. Likewise, to stimulate an inefficient R&D sector in a small country, IPRs have to be very strong. In stimulating southern R&D, the protection of northern and the protection of southern innovations are shown to work as imperfect substitutes. If R&D takes place in the South, strengthening IPRs for both regions' innovators increases welfare in both regions. In contrast, an increase in IPRs that does not surpass the threshold level fails to stimulate R&D, increases the wage gap between the regions and decreases real consumption in the South.

We show that a southern deviation from the national treatment principle (increasing IPRs for domestic firms only), does not harm either region if southern R&D does not take place, and it benefits *both* regions if southern R&D is conducted: By increasing R&D incentives for southern firms, it shifts the southern attention away from the imitation of northern goods.

The next section discusses the related literature, and section 3 describes the model. In section 4, we describe the equilibrium, state the conditions under which southern R&D

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takes place and analyze the effects of different IPR policies on innovative and imitative activity and wages in the two regions. In section 5, the model is calibrated to analyze the welfare and employment effects of stronger IPRs, and section 6 concludes.

2. Related literature

In this section, we compare our results to the conclusions drawn by papers which are most closely related to our work. These papers are different from the seminal North-South models by, i.a., Grossman and Helpman (1991), Deardorff (1992) and Helpman (1993) in that they do not focus on the conflict *between* the innovating North and the imitating South, but are more concerned with the trade-off between imitation and innovation *within* the South.

In Currie et al. (1999), the South has the options to imitate the North or innovate with knowledge dissipating gradually from the North to the southern knowledge base. While not treating the effects of changes in IPRs, Currie et al. (1999) argue that subsidies to the imitation sector have qualitatively the same effects as a loosening of IPRs. The following features distinguish or model from Currie et al. and lead to partially different results: First, we analyze the problem in a semi-endogenous framework to match the empirical observations of non-scale growth as in Jones (1995). Thus policy changes do not imply long-run changes of the growth rate in our model. Second, we include the empirical feature of decreasing returns to R&D into the imitation and innovation processes. This allows the South to engage in R&D even if the wage differences between the regions are large which is not possible in Currie et al.'s framework, but empirically more plausible. Third, while changes in subsidies to imitation do not have any welfare implications for the case in which the South only imitates in Currie et al. (1999), we show that in this no-innovation case stronger IPRs for innovations of both regions decrease welfare, but can help to stimulate R&D if they surpass

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a threshold level. Finally and most importantly, we are able to analyze discriminatory IPR policies as we allow for southern goods to be also subject to innovation. The protection of northern IPRs affects innovation incentives for the South only indirectly by making the alternative (imitation) more costly. In our model, general IPR protection has the direct benefit of increased expected profits for southern innovators. We can thus show that IPRs exclusively for southern goods benefit both regions if southern R&D is present: they increase R&D profitability for the South and thus shift resources away from imitation of the North.

Glass (2010) also analyzes imitation and innovation in the South, but focuses on how imitation encourages R&D by providing the South with a sufficient knowledge base. She builds a product-cycle model in which an exogenous fraction of industries has to engage in imitation before being able to target the market for innovations and analyzes subsidies to northern and southern R&D and imitation. IPRs are not treated explicitly but indiscriminate subsidies to imitation and innovation are considered instead. The result suggests that when imitation is a prerequisite to southern innovation, undirected subsidies can increase the rate of innovation relative to imitation. However, these policies do not have any implications for the wage rate if the South innovates, and welfare changes are not considered in her paper. We emphasize that the focus of our paper is different from Glass (2010): While she analyzes how imitation can serve as a stepping stone to imitation, our paper examines how the South's choice between innovation and imitation is influenced by different IPR policies.

Newiak (2011) analyzes how imitation can encourage R&D in countries whose innovation sector is small compared to those in which the R&D sector is sufficiently large. The results of her model suggest that the effect of IPR policies depend crucially on the state of the R&D sector's development and the main channel of knowledge accumulation in the country. The model does not allow for imitation of southern products so that IPR policies considered in the two papers are different: while in Newiak (2011) an increase in IPRs always means that

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one source of knowledge is harder to access, we reveal a channel through which stronger IPRs are never harmful to R&D and welfare in the South while they can also benefit the North: stronger IPRs for southern innovations.

3. The Model

3.1. Basic set-up of the model

Two regions interact in our model, a group of developed countries (the North) and a group of developing countries (the South). Firms in North and South hire labor for the production of consumption goods and for innovative and imitative research and development (R&D). Labor is perfectly mobile within all sectors across one region, but immobile between the two regions. Thus a single wage rate is paid to all workers within one region. Trade between the two regions is costless. North and South differ in their R&D activities. The North engages in innovation only. As long as a northern variety has not been imitated, its production takes place in the North, and the innovating firm charges the monopoly price on the global market. Once a northern variety has been imitated by the South, its production shifts to the South. The South engages in innovation and the imitation of both northern and southern inventions. If a southern variety has been imitated, its production stays in the South, but it is produced at lower costs by southern imitators.

3.2. Households

Each region is inhabited by a fixed measure of households whose size grows exponentially at a constant rate g_L. Each member of a household is endowed with one unit of labor which he supplies inelastically to the labor market. So the labor supply in North and South at time

t is given by $\ell_t^* = \ell_0^* e^{g_L t}$ and $\ell_t = \ell_0 e^{g_L t}$, respectively.[7] Households in the two regions are identical concerning their preferences and symmetric in their maximization problem. We restrict the outline of the household's problem to the South in the following. Agents in the South maximize the discounted lifetime flow of utility

$$U(t) = \int_t^\infty e^{-(\rho - g_L)t} \ln u(t) dt, \qquad u(t) = \left[\int_0^N x_{j,t}^\alpha dj \right]^{\frac{1}{\alpha}} \tag{1}$$

arising from the consumption of N_t differentiated varieties in each period. $\rho > g_L$ is the rate of time preference. $x_{j,t}$ is the per capita quantity demanded of variety j, α is the degree of product differentiation so that the elasticity of substitution between varieties is $\varepsilon = \frac{1}{1-\alpha}$. Individuals are constrained by their wage and asset income: $\dot{a}_t = (r_t - g_L)a_t + w_t - e_t$ in which e_t stands for consumption expenditure, w_t represents the wage income and r_t is the interest paid on asset holdings a_t. Solving the consumer's maximization problem for both regions we obtain $\bar{x}_{j,t}$, the average per capita demand for variety j by the world consumer at time t:

$$\bar{x}_{j,t} = \frac{\bar{e}_t}{P_t} \left(\frac{p_{j,t}}{P_t} \right)^{-\varepsilon} \tag{2}$$

in which $\bar{e}_t$ represents average consumption expenditure per consumer defined as $\bar{e}_t = (e_t^* \ell_t^* + e_t \ell_t)/L_t$, $p_{j,t}$ is the price of variety j and $L_t = \ell_t + \ell_t^*$. The aggregate price index is defined as $P_t = \left[\int_0^n p_{j,t}^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}}$. Expenditures in the South grow at $\frac{\dot{e}_t}{e_t} = r_t - \rho$ such that individual consumption expenditures e_t grow over time only if the market interest rate r_t exceeds the discount rate ρ.

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[7]Throughout the paper we use the convention to indicate quantities referring to the North by '*' and use no superscript for quantities of the South.

3.3. Research and Development

3.3.1. Innovation

Varieties are invented in the North and in the South. The total amount of varieties invented in the North is given by $n_t^* = n_{R,t}^* + n_{C_N,t}$ in which $n_{R,t}^*$ and $n_{C_N,t}$ represent the number of not imitated and imitated varieties, respectively. Similarly, $n_t = n_{R,t} + n_{C_S,t}$ is the total number of varieties invented in the South with $n_{R,t}$ not yet imitated and $n_{C_S,t}$ already imitated innovations. The total number of varieties available to the world consumer is then given by:[8]

$$N = n^* + n = n_R^* + n_{C_N} + n_R + n_{C_S}. \tag{3}$$

To produce a new variety, R&D firms in the North and South have to develop an innovation blueprint. To obtain this innovation blueprint they hire researchers ℓ_R^* and ℓ_R. The employed researchers' productivity depends on the available amount of knowledge capital which we model as a function of the number of already existing varieties: N^θ. We assume that it is available to both regions equally, but that the regions differ in how efficiently they use it:

$$\dot{n}^* = \dot{n}_R^* + \dot{n}_{C_N} = \frac{\ell_R^* N^\theta}{ag} \tag{4a}$$

$$\dot{n} = \dot{n}_R + \dot{n}_{C_S} = \frac{\ell_R N^\theta}{ag\beta}, \quad \beta > 1, \quad 0 < \theta < 1, \quad g = \frac{\dot{N}}{N}. \tag{4b}$$

We follow Jones (1995) and Gustafsson and Segerstrom (2011) in setting $0 < \theta < 1$ such that the R&D difficulty is decreasing in the number of blueprints, intertemporal knowledge spillovers become weaker over time and strong scale effects are ruled out. The parameter

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[8]To simplify the notation we drop time scripts whenever no risk of ambiguity arises.

a captures the difficulty to innovate in the North so that $\beta > 1$ means that the South is relatively less productive in the innovation process. Further we account for decreasing returns to innovation by letting the global variety growth rate $g = \frac{\dot{N}}{N}$ enter the innovation functions in the denominator.[9]

3.3.2. Imitation

Imitation takes place in the South only. In order to obtain the imitation blueprint of a northern or southern innovation, imitation firms hire labor ℓ_{C_N} and ℓ_{C_S} and use the existing knowledge capital N^θ.[10] So the imitation functions for northern and southern products are described as:

$$\dot{n}_{C_N} = \frac{\ell_{C_N} N^\theta}{\phi_N d a \iota_N}, \quad \iota_N = \frac{\dot{n}_{C_N}}{n_R^*} \tag{5a}$$

$$\dot{n}_{C_S} = \frac{\ell_{C_S} N^\theta}{\phi_S a \iota_S}, \quad \iota_S = \frac{\dot{n}_{C_S}}{n_R}. \tag{5b}$$

ϕ_N and ϕ_S capture the difficulty of imitating northern and southern varieties and are interpreted as the strength of IPR protection in the South. The higher ϕ_N and ϕ_S, the stronger the level of IPR protection and the higher the costs of imitation. Note that we allow for different IPR levels for the inventions from the two regions, so that the South is allowed to discriminate between domestic and foreign firms. ι_N and ι_S are the imitation rates of northern and southern varieties which enter the imitation functions as in Gustafsson and Segerstrom (2011), but with an elasticity of imitation supply of one. Including the imitation rates in the imitation functions again captures the idea of decreasing returns to R&D.[11]

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[9]For literature on decreasing returns to innovation, compare Griliches et al. (1989) and Kortum (1993).

[10]That imitation is costly has been reported by Mansfield et al. (1981) who find average imitation costs of about 65% and imitation time requirement of 70% compared to innovation.

[11]Compare footnote 9.

Finally, we introduce a distance parameter d to allow for a higher imitation difficulty for northern varieties (due to the remote original development and production and possibly higher technological sophistication).

As they operate in the same region as the innovator, imitators of southern goods do not have a labor cost advantage. In order to generate positive profits from imitation, they hire process innovators who improve the production process such that the imitating firm can produce the variety cheaper than the innovation firm. The cost advantage in production η is a positive function of the amount of process innovators ℓ_P employed and a negative function of the cost of developing the imitation blueprint: If it is difficult to copy the technology in the first place, improving the production process should be also more difficult. So η is modeled as a negative function of the labor input ℓ_{C_S} needed to develop the imitation blueprint: $\eta = \bar{\eta} \left(\frac{\ell_P}{\ell_P + \ell_{C_S}} \right)^{\frac{1}{\gamma}}$ with $\eta \in [0, \bar{\eta})$, implying an upper bound cost reduction and γ as the difficulty to improve the production process.

3.4. Production

Labor is the only factor of production. For northern and southern innovators, one unit of labor produces one unit of output. As long as the invention has not been imitated, innovators have monopoly power and maximize their profit $\pi_R^{(*)} = (p_R^{(*)} - w_t^{(*)})\bar{x}_R^{(*)}L$ subject to the demand function (2). Monopolists in the North and South charge a constant mark-up over their marginal costs w^* and w, such that prices and profits for northern and southern innovation firms are given by:

$$p_R^* = \frac{w^*}{\alpha}, \quad \pi_R^* = \frac{1-\alpha}{\alpha} w^* \bar{x}_R^* L \tag{6a}$$

$$p_R = \frac{w}{\alpha}, \quad \pi_R = \frac{1-\alpha}{\alpha} w \bar{x}_R L. \tag{6b}$$

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In the case of imitation, imitators and innovators compete in prices which drives the price down to the innovator's marginal cost of production and the innovating firm shuts down. If the wage differential is not too high ($w^* \leq w/\alpha$), the southern imitator charges a price equal to the northern wage rate w^* to force the northern innovator out of the market. If the wage gap is high ($w/\alpha \leq w^*$), the imitator can charge the monopoly price.[12] As none of our results depends qualitatively on whether narrow or wide gap case is present, we present the model for the wide gap case in the following and outline how the model changes for the narrow-gap case in Appendix A. Due to the process innovation described in the previous section, an imitator of southern innovations produces goods at lower marginal costs $(1-\eta)w$. We assume an upper bound on this cost advantage ($\eta \leq 1 - \alpha$) so that the imitator charges a price equal to the southern wage rate. The price and the profits for imitated northern and southern goods are given by:

$$p_{C_N} = \frac{w}{\alpha}, \qquad \pi_{C_N} = \frac{1-\alpha}{\alpha} w \bar{x}_{C_N} L, \qquad w^* \geq \frac{w}{\alpha} \tag{7a}$$

$$p_{C_S} = w, \qquad \pi_{C_S} = \eta w \bar{x}_{C_S} L, \qquad \eta \leq 1 - \alpha. \tag{7b}$$

3.5. Financial sectors

The value of an innovating or imitating firm v_R or v_C is given by its expected discounted profits. As there is free entry to R&D and imitation, these expected discounted profits have to be equal to the cost of the respective activity. For innovating firms, the cost consists of the wage paid to the researchers. For imitating firms, it is the wage paid to the reverse engineers (and process innovators for imitators of southern varieties). Using (4) and (5) to

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[12]These cases are referred to as the narrow-gap case and the wide-gap case by Grossman and Helpman (1991).

determine the amount of labor for these activities, the firm values for innovators in North and South and imitators in the South are:

$$v_R^* = \frac{w^* ag}{N^\theta} \qquad\qquad v_R = \frac{w\beta ag}{N^\theta} \qquad\qquad (8a)$$

$$v_{C_N} = \frac{w\phi_N a\iota_N}{N^\theta} \qquad\qquad v_{C_S} = \frac{w\phi_S a\iota_S}{N^\theta(1 - (\eta/\bar{\eta})^\gamma)} \qquad\qquad (8b)$$

There is perfect capital mobility between innovation, imitation and production sectors within one region, but financial autarky in North and South. Agents in the North can decide between holding the market portfolio with a safe return r^* or shares of the northern innovation firms which pay a return π_R^*/v_R^*. This return has to be adjusted by the change in the value of the firm $\dot{v}_R^*/v_R^*$ and the risk of being copied $\dot{n}_{C_N}/n_R^*$. In the South, agents have the choice between gaining the risk free rate r and holding shares of southern innovation or imitation firms. No-arbitrage between these choices implies $\frac{\pi_R^*}{v_R^*} + \frac{\dot{v}_R^*}{v_R^*} - \frac{\dot{n}_{C_N}}{n_R^*} = r^*$ for the North and $\frac{\pi_R}{v_R} + \frac{\dot{v}_R}{v_R} - \frac{\dot{n}_{C_S}}{n_R} = r = \frac{\pi_{C_N}}{v_{C_N}} + \frac{\dot{v}_{C_N}}{v_{C_N}} = \frac{\pi_{C_S}}{v_{C_S}} + \frac{\dot{v}_{C_S}}{v_{C_S}}$ for the South.

3.6. Labor markets

Finally, labor market clearing in the North and South requires that the sum of workers employed in the R&D and production sectors equals the total labor force in each region. In the North, labor is allocated into R&D and production: $\ell^* = \ell_R^* + \ell_Y^*$. In the South, labor is allocated into R&D, the imitation of northern goods, the imitation of southern goods, process innovation and production: $\ell = \ell_R + \ell_{C_N} + (\ell_{C_S} + \ell_P) + \ell_Y$.

4. The balanced growth path and the effects of IPRs

In this section, we define the equilibrium and analyse the conditions under which innovation takes place in the South. We then analyze the effect of different IPR policies for an

equilibrium with southern innovation. The model without southern innovation is described in [Appendix B](#).

4.1. Definition of the equilibrium and long-run growth

The equilibrium is given by a set of prices, wages and interest rates in North and South such that the allocation of labor into the different sectors, varieties and their supply, consumption expenditures and asset holdings (1) solves the households' utility maximization problem and firms maximize profits and (2) labor, goods and financial markets clear given the free market entry of firms. In this steady state equilibrium, variety growth $g \equiv \dot{N}/N$, the South-North wage ratio $\omega \equiv w/w^*$, the imitation rates ι_N and ι_S, the optimal cost advantage of southern imitative production $\eta^\star$, the variety shares $\xi_R^* \equiv n_R^*/N$, $\xi_R \equiv n_R/N$, $\xi_{C_N} \equiv n_{C_N}/N$ and $\xi_{C_S} \equiv n_{C_S}/N = 1 - \xi_R^* - \xi_R - \xi_{C_N}$, and the shares of labor employed in the different sectors of each region are constant. Further, constant consumption expenditures imply that the risk-free interest rates in North and South are equal to the rate of time preference $\rho = r^* = r$ in steady state.

As the variety shares are constant in steady state, all varieties have to grow at the same rate $g = \dot{N}/N = \dot{n}_R^*/n_R^* = \dot{n}_R/n_R = \dot{n}_{C_N}/n_{C_N} = \dot{n}_{C_S}/n_{C_S}$. Dividing (4) by N and using the fact that the R&D employment ratio ℓ_R^*/ℓ^* is constant in steady state the equilibrium growth rate is determined as

$$g = \frac{g_L}{1 - \theta}. \tag{9}$$

The growth rate is finite and positive for $\theta < 1$. This semi-endogenous growth implies that policy actions do not have any effect on the long-run growth rate.

4.2. The threshold to innovation in the South

We turn now to answering the first question of the paper: Which factors determine the innovation threshold observed in the data (compare figure 1)? To answer this question, we consider the conditions under which innovation and imitation are beneficial in the two regions: Rearranging the no-arbitrage conditions with respect to the firm values and equating with (8) and realizing that $\dot{v}_R^*/v_R^* = \dot{v}_R/v_R = \dot{v}_{C_N}/v_{C_N} = \dot{v}_{C_S}/v_{C_S} = -\theta g$, we arrive at four conditions balancing profits and costs of innovative and imitative activities in North and South:

$$\frac{\pi_R^*}{\rho + \theta g + \iota_N} = \frac{w^* a g}{N^\theta} \tag{10a}$$

$$\frac{\pi_R}{\rho + \theta g + \iota_S} = \frac{w \beta a g}{N^\theta} \tag{10b}$$

$$\frac{\pi_{C_N}}{\rho + \theta g} = \frac{w \phi_N d a \iota_N}{N^\theta} \tag{10c}$$

$$\frac{\pi_{C_S}}{\rho + \theta g} = \frac{w \phi_S a \iota_S}{N^\theta (1 - (\eta/\bar{\eta})^\gamma)}. \tag{10d}$$

The left-hand side of (10) represents the benefit (the appropriately discounted profits) from innovation and imitation, whilst the right-hand side represents the cost (wage payments) of the respective activity.[13] These conditions are crucially affected by the level of IPRs (ϕ_S and ϕ_N): first, they directly determine the cost of imitation (the right-hand sides of (10c) and (10d)) and second, via their effect on the imitation rates, they affect the expected profits from innovation (the left-hand sides of equations (10a) and (10b)). As the South does only

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[13]Note that the cost advantage in the production of southern products η is determined optimally by the southern imitation firm. To set η optimally, the marginal revenue (the increase in profits due to the decrease in the production costs) and the marginal cost of hiring a process innovator (the wage rate) are equated. Thus, both sides of (10d) are differentiated with respect to ℓ_P. The optimal cost advantage can then be written as $\eta^\star = \bar{\eta} \left(\frac{1}{1+\gamma} \right)^{\frac{1}{\gamma}}$.

engage in R&D if the expected profits and the associated costs from performing R&D are at least as attractive as the imitation of northern varieties we thus expect three parameters to crucially influence the existence of southern innovation: First, the higher the relative research inefficiency β the higher the cost of developing one blueprint and the higher the required profits to cover these costs. Second, expected profits to R&D depend negatively on the risk of being imitated ι_S which is directly determined by the level of IPRs for southern innovations ϕ_S (which we explicitly show in the next section). Third, the decision to engage in R&D depends on the ease of imitation of northern goods which is influenced by the protection of northern goods ϕ_N: the lower ϕ_N the easier is imitation compared to innovation. Finally, the southern decisions have to be consistent with the southern resource constraint (labor market clearing).

Combining the southern cost-benefit conditions (10b)-(10d) with the southern labor market clearing equation, we obtain the condition under which employment in the southern innovation sector is positive:

$$\frac{\ell}{\ell^*} > d\phi_N \left(\frac{\iota_N}{g}\right)^2 \left(\frac{\Lambda_1}{\Lambda_1 + \iota_N}\right), \quad \iota_N = \frac{\beta}{d\phi_N} \frac{\Delta_1 \phi_S (\rho + \theta g)g}{\Delta_1 \phi_S (\rho + \theta g) - \eta^\star g} \tag{11}$$

with $\Lambda_1 = (1-\alpha)g + \alpha(\rho + \theta g)$. From (11) follows that the higher the protection of northern or southern innovations (the higher ϕ_S and ϕ_N) the more likely the South engages in research. Intuitively, the South is, c.p., more likely to engage in R&D if its research efficiency is high (β is low). For a given southern R&D efficiency, IPRs for northern and southern IPRs are substitutes to a certain degree: If ϕ_N is high and therefore the costs of imitating the North are high compared to conducting own research, expected profits from R&D can be smaller and therefore IPRs for southern goods can be weaker. Further, the higher the cost of original research in the South (the higher β) the stronger IPRs have to be for northern and southern products in order to make R&D comparatively profitable. Finally, the existence of southern

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R&D is more likely if the southern labor force is large. This implies that for given levels of IPR protection and research ability, large countries are more likely to engage in innovation. We plot the IPR threshold ($\ell_R = 0$) in figure 2 for illustration.
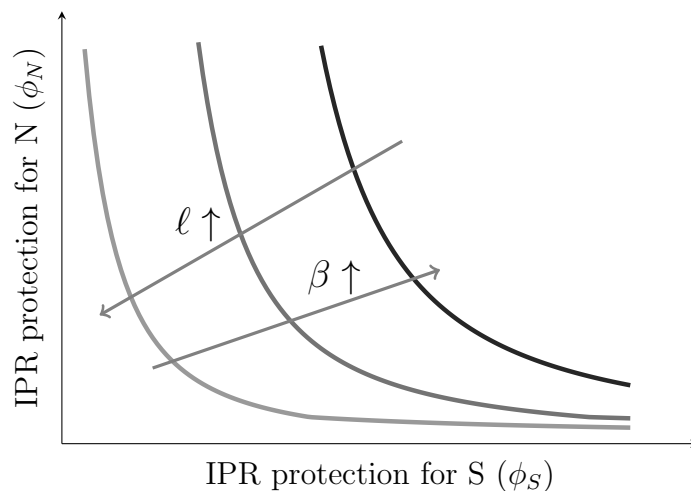

Figure 2: IPR threshold for southern research employment.

Innovation takes place for all combinations of ϕ_S and ϕ_N on the right hand side of the isoquant. The figure demonstrates that the South can go from a phase of solely imitating the North to a phase with own original R&D if the southern research efficiency or IPRs are sufficiently increased. It also reveals that in order to stimulate R&D in countries which a less efficient research sector IPR protection has to be stronger than in countries with efficient R&D sectors. The results are summarized in

Proposition 1 *(i) Stronger IPRs can stimulate southern innovation if they surpass a threshold level. (ii) This threshold level is higher the less efficient the southern research sector and the smaller the relative size of the southern population. (iii) The protection of southern and northern innovations work as imperfect substitutes in encouraging southern R&D.*

If (11) is not satisfied the cost-benefit conditions (10b) and (10d) cease and the model collapses to the standard North-South model without southern innovation. While we focus on

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the case in which southern R&D takes place in the following, we describe the no-innovation case in Appendix B.

4.3. IPR policy effects on the incentives to innovate and imitate

To obtain the rates at which northern and southern products are imitated, we combine the cost-benefit conditions (10b) and (10d) as well as (10a) with (10d), substitute for the profits and using the demands for varieties (2):

$$\iota_S = \frac{\eta^\star \beta (\rho + \theta g) g}{\Delta_1 \phi_S (\rho + \theta g) - \eta^\star \beta g} \tag{12a}$$

$$\iota_N = \frac{\beta}{d \phi_N} \frac{\Delta_1 \phi_S (\rho + \theta g) g}{\Delta_1 \phi_S (\rho + \theta g) - \eta^\star \beta g}, \tag{12b}$$

with $\Delta_1 = (1 - \alpha) \alpha^{\varepsilon - 1} \frac{(1 + \gamma)}{\gamma}$.[14] Suppose first that the South follows the national treatment principle and chooses to protect domestic and foreign goods equally (formally: set $\phi_N = \phi_S = \phi$). Increasing ϕ will then decrease the rates at which domestic and foreign goods are imitated. However, the South could also chose to discriminate between domestic and foreign innovators by increasing only either ϕ_N or ϕ_S. Increasing IPRs for northern firms will decrease the rate at which northern firms are imitated, but leave the risk of being imitated for southern innovators unaffected. In contrast, if the South choses to increase IPRs for domestic innovations only ($\phi_S \uparrow$), both rates of imitation decrease. This effect results from the impact of ϕ_S on southern innovation: If southern goods are better protected, southern innovators face a lower risk of being imitated and consequently their expected profits increase. This makes own innovation more attractive compared to the imitation of both northern and southern goods which leads to the decline of the imitation rates. In line with this reasoning, policies which aim at increasing the southern research efficiency (decreasing β) decrease

[14]As ι_S has to be non-negative, the parameters of the model are constrained to $\eta^\star \beta g < \phi_S \Delta_1 (\rho + \theta g)$.

the imitation rates by decreasing the innovation costs and thus making southern innovation more attractive compared to imitation.

Proposition 2 *In an equilibrium with southern innovation the rates at which northern and southern innovations are imitated are decreasing in (i) an increase in IPRs for all varieties, (ii) an increase in IPRs exclusively for southern innovations and (iii) an increase in the southern research efficiency. Increases in IPRs exclusively for northern goods decrease the imitation risk for northern goods, but leave the imitation rate for southern innovations unaffected.*

How do these changes of imitation risks relate to the allocation of labor into the different sectors in North and South? We use the northern labor market clearing condition and combine it with the cost-benefit conditions to get the amount of labor allocated into R&D and production in the North:

$$\ell_R^* = \frac{(1-\alpha)(g+\iota_N)}{\Lambda_1 + \iota_N}\ell^*, \qquad \ell_Y^* = \frac{\alpha(\rho+\theta g+\iota_N)}{\Lambda_1 + \iota_N}\ell^*. \tag{13}$$

The amount of labor employed in the northern R&D sector is increasing in the rate at which northern products are copied: If northern innovations are copied at a high rate, the production of northern inventions shifts to the South quickly. As a consequence, labor is set free from the production sector to the innovation sector. It follows that policies which decrease the imitation risks for northern firms ($\phi_N \uparrow$ or $\phi_S \uparrow$ or $\beta \downarrow$), also decrease the share of labor employed in the northern research sector.

To obtain the allocation of southern labor into the imitation of northern goods, we combine (13) with the imitation function for northern goods:

$$\ell_{C_N} = \frac{\phi_N \iota_N^2}{g}\frac{(1-\alpha)}{(\Lambda_1 + \iota_N)}\ell^*. \tag{14}$$

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Using (12b), we can show that employment in the imitation sector for northern goods is decreasing in the strength of IPR protection for northern and southern goods ϕ_N and ϕ_S and increasing in the southern research inefficiency β. The higher the protection of northern goods ϕ_N the costlier the imitation of northern goods, so that southern innovation and imitation of southern goods becomes more attractive. The higher the protection of southern goods ϕ_S, the smaller the risk of being copied for the South, the more attractive is southern research which shifts resources from the imitation of northern goods to own innovation. This result again reveals that an IPR policy in favor of domestic innovators (increase ϕ_S only) can shift resources away from the imitation of foreign innovations.

To obtain the number of workers employed in the southern innovation sector, we use (14) and the cost-benefit conditions (10b)-(10d) :

$$\ell_R = \left(\ell - \phi_N \left(\frac{\iota_N}{g} \right)^2 \left(\frac{\Lambda_1}{\Lambda_1 + \iota_N} \right) \ell^* \right) \frac{(1-\alpha)(g + \iota_S)}{\Lambda_1 + \iota_S + \frac{1-\alpha}{\eta^\star} \frac{\gamma+1}{\gamma} \frac{\phi_S}{\beta} \left(\frac{\iota_s}{g} \right)^2 \Lambda_2}, \qquad (15)$$

in which $\Lambda_2 = \eta^\star g + (1 - \eta^\star)(\rho + \theta g)$. Equation (15) consists of two terms. The number of workers which are *not* employed in the imitation of northern products and their production is given by the first factor. The second factor gives the fraction of these workers employed in original southern R&D. Southern R&D employment is increasing in the level at which northern and southern inventions are protected (ϕ_N and ϕ_S).[15] When protecting northern goods more strongly, imitation of these goods becomes more costly and thus becomes relatively unattractive compared to innovation, thus R&D employment increases. When protecting southern inventions more strongly, R&D employment increases for two reasons: First, imitation of southern products becomes more costly and therefore relatively less attractive compared to R&D. Second, southern R&D becomes more attractive as the risk of being imitated declines. We summarize these findings in the following proposition:

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[15] A sufficient (but not necessary) condition for the latter statement is that $\phi_S < \frac{2}{\Delta_1(\rho + \theta g)}$.

Proposition 3 *An increase in the level of IPRs for northern or southern goods or an increase in the efficiency of the southern research sector (i) increases employment in the southern research sector, (ii) decreases employment in the northern research sector and (iii) decreases employment in the imitation sector which targets northern goods.*

The effects of IPR policies on the labor allocated to the imitation of southern inventions $\ell_{C_S} = \frac{\phi_S \iota_S}{g\beta} \frac{\iota_S}{\iota_S + g} \ell_R$ is explored in the numerical part (section 5).

4.4. IPR policy effects on wages and welfare

After analyzing how IPRs influence the southern incentives to innovate and imitate, we now look at whether these changes in incentives and labor allocation are beneficial to either of the regions. First, we look at the response of the wage differential between the two regions as a measure of their difference in development. Second, we outline the way we are going to measure changes in welfare due to IPR changes which will be quantified in the numerical section. Combining the cost-benefit conditions (10a) and (10b) with the equations for the imitation rates, we determine the relative wage between South and North $\frac{w}{w^*}$:

$$\omega = \left(\frac{1}{\beta} + \frac{1}{d\phi_N(\rho + \theta g)} - \frac{\eta^\star}{\Delta_1 \phi_S(\rho + \theta g)} \right)^{\frac{1}{\varepsilon}}. \tag{16}$$

The relative wage between South and North is determined by the southern research inefficiency (β) and the IPRs for northern and southern goods (ϕ_N and ϕ_S). Intuitively, the more efficient the southern research sector compared to the northern one (the lower β), the lower the wage differential between the regions. The equilibrium wage reveals that the protection of northern and southern goods have different effects on how far the South is behind in terms of wages: Stronger protection of northern goods increases the wage gap, stronger protection for domestic innovators decreases the wage gap. While both IPR policies increase the cost

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of imitation, stronger protection for southern goods also raises the profitability of southern R&D and thus southern wages. Suppose again, that the South follows the national treatment principle and protects northern and southern innovations equally strong ($\phi_N = \phi_S = \phi$). Then differentiating (16) with respect to ϕ gives the following condition:

$$\frac{\partial \omega}{\partial \phi} \gtrless 0 \quad \text{if} \quad \iota_S \gtrless \iota_N. \tag{17}$$

This condition says that stronger IPRs increase the southern wage rate relative to the northern one if southern products are imitated at a higher rate, but decreases it if northern products are subject to higher imitation. For the national treatment case $\iota_S > \iota_N$ is fulfilled if $d > \frac{\Delta_1}{\eta^*}$. This says that stronger IPRs decrease the wage difference between the regions only if northern products are sufficiently difficult to imitate.

Proposition 4 *In an equilibrium with southern innovation, an increase in IPRs for southern innovations decreases the wage gap between South and North, while stronger IPRs for northern goods increase the wage gap. A simultaneous increase in IPRs for northern and southern goods decreases the wage differential between the regions only if northern innovations are sufficiently difficult to imitate.*

Finally, in order to make welfare predictions for IPR policy changes, we solve for asset holdings, consumer expenditures and the economic growth rate. The aggregate value of northern assets A^* is the product of the number of non-copied northern innovations and the value of a northern innovation firm $A^* = n_R^* v_R^*$. Substituting v_R^* by (8) yields $A^* = \xi_R^* w^* a g N^{1-\theta}$. The southern aggregate asset value A consists of the sum of the values of the assets from innovating and the two kinds of imitating firms, so that it is given by $A = \left(\xi_R g \beta + \xi_{C_N} \phi_N \iota_N + \xi_{C_S} \frac{1+\gamma}{\gamma} \phi_S \iota_S \right) a w N^{1-\theta}$. It follows that per capita asset holdings in the North $a^* = A^*/\ell^*$ and the South $a = A/\ell$ are constant in equilibrium. We can then use the

budget constraint of the representative consumer to determine the per capita consumption expenditure levels e^* and e as functions of the variety shares and wage rates. The aggregate price level is given by $P_t = N_t^{1/(1-\varepsilon)} (\xi_R^*(p_R^*)^{1-\varepsilon} + \xi_R(p_R)^{1-\varepsilon} + \xi_{C_N}(p_{C_N})^{1-\varepsilon} + \xi_{C_S}(p_{C_S})^{1-\varepsilon})^{1/(1-\varepsilon)}$. Let $c_t^* \equiv e_t^*/P_t$ and $c_t \equiv e_t/P_t$ denote real consumption expenditure in North and South. Following Dixit and Stiglitz (1977), this measure also represents consumers' utility at time t; we thus have $c_t^{(*)} = u_t^{(*)}$. We solve for the equilibrium utilities of North and South using (1):

$$u_t^* = \frac{e_t^*}{P_t} \equiv c_t^*, \quad u_t = \frac{e_t}{P_t} \equiv c_t. \tag{18}$$

As nominal per capita consumption expenditure $e^{(*)}$ is constant in steady state, but the aggregate price level P_t is decreasing over time, utility is growing over time. As utility is proportional to consumption expenditure when prices are held fixed it can be interpreted as real consumption growth. Thus the growth rate of the utility can be interpreted as economic growth. Real consumption growth in this model is given by $\dot{u}^*/u^* = \dot{u}/u = \dot{c}^*/c^* = \dot{c}/c = g/(\varepsilon - 1) \equiv g_c > 0$. As the steady state growth rate of real consumption in both regions is equal and independent of the policy parameters, a long-run welfare analysis of changes in the parameters of interest on welfare can be simplified to looking at changes in c_0^* and c_0.[16] As the changes in c_0^* and c_0 are ambiguous, we leave the analysis of welfare changes in response to stronger IPR protection and different development stages of the southern research sector for the numerical analysis in this paper.

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[16]This approach has been taken by Gustafsson and Segerstrom (2011).

5. Numerical analysis

5.1. Calibration of the model

Providing analytical results for the effects of chances in IPR protection on certain economic outcomes proved to be unfeasible in the previous section. In this section, to analyze the effects of changes in IPR protection on real consumption levels in both regions and the allocation of labor into the imitation of southern innovations, we calibrate the model with empirically sound parameters. The main aim of this section is not to get reliable quantitative predictions of the effects of stronger IPRs, but mainly to provide a qualitative idea about their effects on welfare, as measured in real consumption, in both regions.

To calibrate the model, parameters are set to match the following target moments[17]: The real interest rate takes a value of 7% according to the average real US stock market return over the past century estimated by Mehra and Prescott (1985). This implies a subjective discount rate ρ of the same value. Basu (1996) and Norrbin (1993) estimate a markup of 40% over marginal costs, determining the degree of differentiation between varieties α to be 0.714. The population growth rate $g_L = 1.68\%$ represents the average annual world population growth rate between 1960-2008 reported by the World Bank World Development Indicators 2009 (World Bank, 2009). Only the ratio of population size, ℓ_0/ℓ_0^*, is relevant for the steady state equilibrium. Comparing population in middle-income to high-income coutries, this ratio is given by approximately 4.35, including low-income countries in the southern population, the ratio is about 5.27 for 2008 figures (World Bank, 2009). Due to our general notion of the South we include low-income countries and use a value of $\ell_0/\ell_0^* = 5.27$. To achieve a utility growth rate g_c of about 2%, reflecting the average US GDP per capita

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[17]For the sake of comparability, we calibrate the target moments as in Gustafsson and Segerstrom (2011) when applicable.

growth rate from 1950-1994 as reported in Jones (2005), we set the value of intertemporal R&D spillovers $\theta = 0.67$. Following Gustafsson and Segerstrom (2011), we aim for a cost advantage of imitators of the South of $\eta^\star = 10\%$, leading to a parameterization of $\bar{\eta} = 0.18$ and $1/\gamma = \theta$. As only the relative research difficulty determines the steady state of the model, we set $ag = 1$ to normalize the parameters. For the benchmark case, we assume a research inefficiency of the South of $\beta = 3$, which implies a three times higher R&D labor requirement. The distance parameter for imitation d is set to 10. Given those values, we set the parameters for IPR protection to $\phi_N = \phi_S = 1.5$ which results in plausible imitation rates of about 2% of northern innovations and 9% of southern innovations.

5.2. Change of IPR protection for northern and southern innovations

The first simulation shows the effects of a general change in IPR protection in the South, i.e. when $\phi_N = \phi_S = \phi$. The fourth column contains the benchmark case with $\phi = 1.5$ for which the South is active in original R&D ($\ell_R > 0$) and the wage differential is such that the wide-gap case applies ($\omega < \alpha$). For lower values of ϕ up to the threshold value of about 1, no innovation takes place in the South as R&D incentives are too weak given the ease of imitating the North. Table 1 shows that the South loses from the strengthening of IPR protection both in terms of real consumption and relative wage until the innovation threshold is reached. This is due to the detrimental effect of IPR protection for northern varieties. The South relies on imitation of the North to obtain production blueprints. With higher protection, imitation employment leads to fewer imitation blueprints. The lower marginal productivity reduces wages and leads to an increase in production of each variety as their price declines. Overall, employment shares do not change in the South up to the threshold. However, fewer varieties are produced in larger quantities for lower prices. Northern research declines slightly before and more noticeable after the threshold is passed.

Table 1: Changing IPR protection for northern and southern goods

IPR protection	$\phi_S = \phi_N$	no innov.		with innov.		
		0.6	1	1.1	1.5	2.25
relative wage S/N	ω	0.647	0.594	0.599	0.641	0.674
imitation rate N	ι_N	0.062	0.046	0.038	0.019	0.010
imitation rate S	ι_S	0	0	0.181	0.090	0.047
innov. labor N	ℓ_R^*	0.214	0.205	0.201	0.185	0.176
fraction innov. labor S	ℓ_R/ℓ	0	0	0.005	0.029	0.054
fracion labor imit. N	ℓ_{C_N}/ℓ	0.164	0.164	0.134	0.053	0.023
fraction labor imit. S	$\ell_{C_S}^a/\ell$	0	0	0.008	0.027	0.030
real cons. N	c^*	6.028	5.989	6.222	7.488	8.865
real cons. S	c	4.148	3.743	3.825	4.609	5.621
rel. cons. N/S	c^*/c	1.453	1.600	1.627	1.625	1.577

Notes: ^{a} sum of imitators of the South and process innovators.

Figure 3 shows the detailed development of research employment in the South and real consumption. The labor allocation in the South is comparable to the case in which only protection of southern innovations is improved. However, the fall in imitation of the North is more pronounced as both IPR protection levels contribute to a shift from imitation of the North to research in the South.

After an initially high imitation employment and therewith imitation rate of southern innovations, both reduce as a consequence of better protection and increase profitability of southern original R&D compared to imitation. Surprisingly, the North does not benefit from an increase in the protection of its goods before the threshold. This is due to the reduction of innovation on the one side, but more importantly due to reduced supply of lower priced imitated goods on the other side. Once the threshold is passed, both regions experience an increase in real consumption with the South starting to catch up in relative consumption.
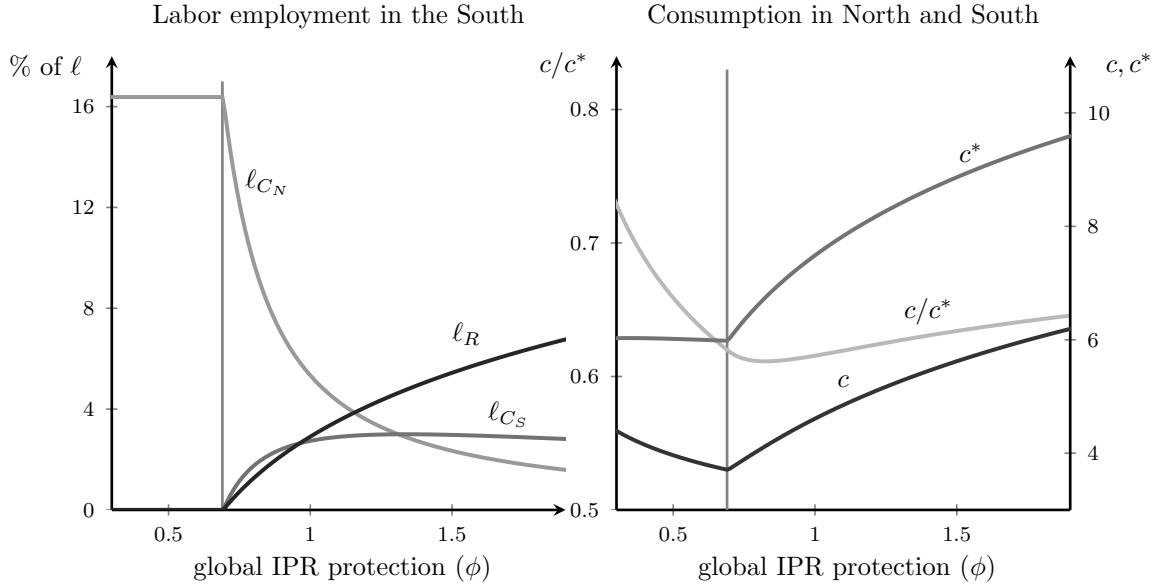
Labor employment in the South   Consumption in North and South

Figure 3: Proportionate change of IPR protection.

5.3. Change of IPR protection for southern innovations

The simulation in table 2 shows the change of key variables that result from changes of the level of IPR protection for southern innovations ϕ_S only, thus deviating from the national treatment principle. As the northern IPR protection level is unchanged, the threshold has slightly decreased to about 0.95. For lower values of ϕ_S, no innovation takes place in the South. As only southern IPR protection is varied, changes up to the threshold level do not affect the equilibrium. Once the threshold is passed, innovation in the South starts and new varieties developed in the South attract imitation. Thus labor employed in the imitation of southern goods first increases, but later declines steadily with the rise of IPR protection. At the same time, northern products are less frequently imitated as southern resources are shifted to innovation and imitation of the South. As more innovations stay in the North, its R&D efforts decrease slightly.

Figure 4 illustrates the development of southern research employment and real consumption in greater detail. Up to the threshold level, indicated by the gray vertical bar, changes in

Table 2: Changing protection of southern goods

IPR S innov.	ϕ_S	no innov.		with innov.		
		0.75	0.95	1	1.5	1.75
relative wage S/N	ω	0.555	0.555	0.563	0.641	0.660
imitation rate N	ι_N	0.036	0.036	0.033	0.019	0.017
imitation rate S	ι_S	0	0	0.237	0.090	0.069
innov. labor N	ℓ_R^*	0.199	0.199	0.197	0.185	0.183
fraction innov. labor S	ℓ_R/ℓ	0	0	0.002	0.029	0.038
fracion labor imit. N	ℓ_{C_N}/ℓ	0.164	0.164	0.146	0.053	0.043
fraction labor imit. S	$\ell_{C_S}^a/\ell$	0	0	0.005	0.027	0.028
real cons. N	c^*	5.927	5.927	6.047	7.488	7.954
real cons. S	c	3.433	3.433	3.507	4.609	5.007
rel. cons. N/S	c^*/c	1.726	1.726	1.724	1.625	1.589

Notes: [a] sum of imitators of the South and process innovators.

ϕ_S remain without effect. Concerning the labor employment in the South, resources are quickly withdrawn from the imitation of the North once the threshold is passed and shifted to southern innovation and imitation of the South. While employment in imitating the South[18] initially exceeds the research employment, original research eventually becomes the largest research sector in the South. Real consumption expenditure and therewith utility are positively affected by increases in ϕ_S above the threshold level. The North benefits from higher returns to innovation as well as more product varieties provided by the South which more than compensates the higher fraction of goods supplied monopolistically. The same holds for the South, which can catch up in relative consumption to the North.

5.4. Summary of main numerical results

We conclude from this section that the long-run consequences of a strengthening of IPRs following the national treatment principle is welfare decreasing for the South, while it has

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[18]Note that ℓ_{C_S} includes both imitators and process innovators in the graphs.
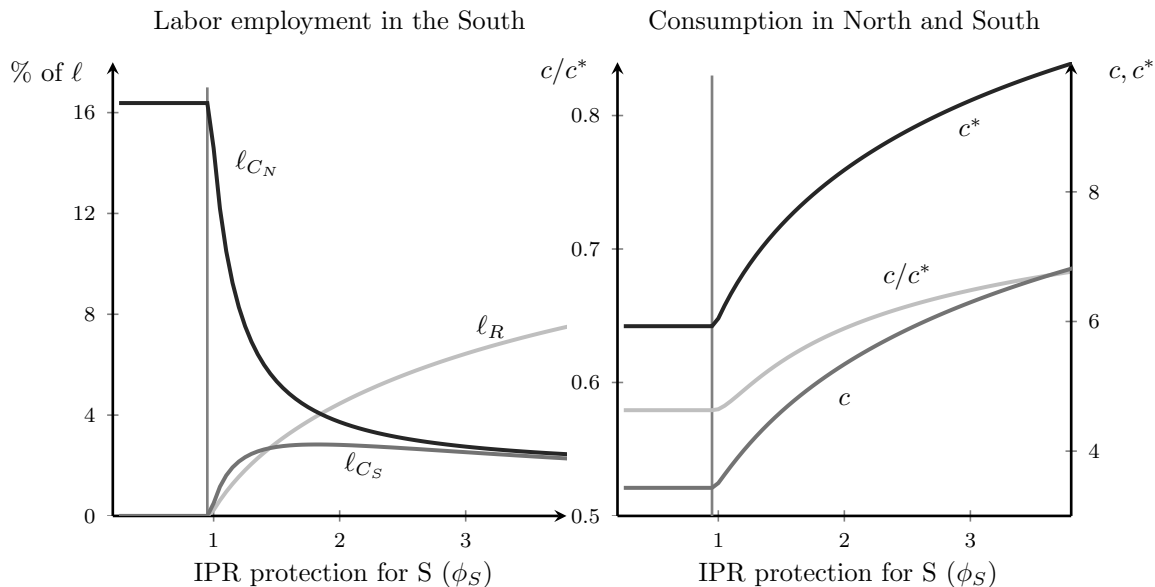
Figure 4: Change of protection of southern innovations.

negligible effects for the North. An increase in IPRs for southern goods only which fails to pass the threshold level and thus fails to stimulate R&D in the South is shown to have no effect on any of the regions welfare outcomes. With southern innovation, stronger IPRs for either of both northern and southern goods are related to higher welfare in both regions. Finally, we conclude that a deviation of the South from the national treatment principle by raising IPR standards for domestic firms only raises welfare in *both* regions by shifting the southern resources away from the imitation of goods to original innovation.

6. Concluding Remarks

This paper gives a theoretical explanation for the empirically observed threshold level in the relationship between IPRs and innovative activity. To explain this relationship, we account for the increased R&D efforts by developing countries and extend the previous literature to allow not only for southern R&D and imitation of northern goods, but also imitation of southern inventions. Further, to analyze the effects of southern IPR policies deviating

from the national treatment principle (by raising IPRs for southern goods more strongly than for northern goods), we allow for different degrees of IPR protection for northern and southern varieties. We show that for low levels of IPRs and low research efficiency in the South, southern R&D does not take place. The model therefore nests the results of "standard" North-South models for the no-innovation case: If IPRs are strengthened in this stage of southern development, they do not stimulate R&D and decrease wages and welfare in the South. However, in accordance with the empirically observed patterns, we show that if IPRs surpass a critical level, they help to spur innovation in the South and increase welfare in both regions. The critical IPR level depends on the southern R&D efficiency and labor resources such that large countries or countries with a high research efficiency engage in R&D even under relatively weak protection. Likewise, to stimulate a very inefficient R&D sector in a small country, IPRs have to be very strong. We show that the protection of southern and northern innovations can work as imperfect substitutes in encouraging southern R&D though they work via different channels: While the protection of southern innovations affects expected profits from R&D directly, stronger protection of northern goods achieves this effect mainly by making the imitation of northern goods more expensive. Finally, we can thus show that an increase of IPRs exclusively for southern goods does not harm any region in the no-innovation case. However, if southern R&D takes place, such a policy benefits both regions by increasing the southern innovation incentives and thus shifting its resources away from the imitation of northern goods.

Appendix A. The Model in the narrow gap case

In this section, we describe how the model changes if it is solved for an equilibrium in which the wage gap is narrow, i.e. $\omega \geq \alpha$. The main change occurs through the fact that now

imitators of northern products cannot charge the monopoly price, but charge the innovator's marginal cost to exclude him from the market. Equation (7a) becomes

$$p_{C_N} = w^*, \quad \pi_{C_N} = (w^* - w)\bar{x}_{C_N}L. \tag{7a$'$}$$

From this follows that the profits used in the cost-benefit equation (10c) change. Accordingly, the equations which are derived with the help of this cost-benefit condition also change. These are the equations for the rate at which northern varieties are copied, the wage gap, and the equation for the employment in the southern research sector:

$$\iota_N = \frac{(1-\omega)(\rho+\theta g)g}{\frac{\gamma}{1+\gamma}\Delta_1 d\phi_N(\rho+\theta g)\omega - (1-\omega)g} \tag{12b$'$}$$

$$\omega^{\varepsilon-1} - \omega^{\varepsilon}\left(1 + (1-\alpha)\alpha^{\varepsilon-1}\frac{\rho+\theta g}{g}d\phi_N\right) = \frac{\gamma}{1+\gamma}\frac{d\phi_N}{\phi_S}\eta^* - (1-\alpha)\alpha^{\varepsilon-1}\frac{\rho+\theta g}{g}\frac{d\phi_N}{\beta} \tag{16$'$}$$

$$\ell_R = \frac{(1-\alpha)(g+\iota_S)}{\Lambda_1 + \iota_S + \frac{1-\alpha}{\eta^\star}\frac{1+\gamma}{\gamma}\frac{\phi_S}{\beta}\left(\frac{\iota_S}{g}\right)^2\Lambda_2}\left(\ell - \frac{1-\alpha}{1-\omega}d\phi_N\left(\frac{\iota_N}{g}\right)^2\frac{(1-\omega)g+\omega(\rho+\theta g)}{\Lambda_1+\iota_N}\right). \tag{15$'$}$$

The function $f(\omega) \equiv \omega^{\varepsilon-1} - \omega^{\varepsilon}(1+(1-\alpha)\alpha^{\varepsilon-1}\frac{\rho+\theta g}{g}d\phi_N)$ and the constant $W \equiv \frac{\gamma}{1+\gamma}\frac{d\phi_N}{\phi_S}\eta^* - (1-\alpha)\alpha^{\varepsilon-1}\frac{\rho+\theta g}{g}\frac{d\phi_N}{\beta}$ are illustrated in figure A.5. From differentiating $f(\omega)$ follows that $df(\omega)/d\omega < 0$ if $\alpha/(1 + \frac{\gamma}{1+\gamma}\Delta_1 d\phi_N(\rho+\theta g)) < \omega$. As the denominator of the expression is greater than one the relation always holds in the narrow-gap case ($\alpha \leq \omega$). Consequently, the economy is on the downward sloping side of the wage parabola. Further we know that W will be negative if the imitation rate of southern products is non-negative (compare equation (12a)). Figure A.5 also illustrates the effects of changes in the southern innovation productivity β and the levels of IPR protection ϕ_N and ϕ_S. The wage gap is higher the higher the southern disadvantage in innovation β and the lower the protection of southern goods ϕ_S: The higher β (the lower ϕ_S) the more attractive imitation becomes. When the

copy rates ι_N and ι_S rise, expected profits from innovation declines in both regions. At the same time, due to the higher imitation rates, imitation is also more costly. As a result, the southern wage declines more strongly than the northern one so that the wage gap increases. Applying the implicit function theorem to the wage function, one can see that the relative wage is falling (wage gap is rising) with stronger IPRs for northern goods ϕ_N. While not all
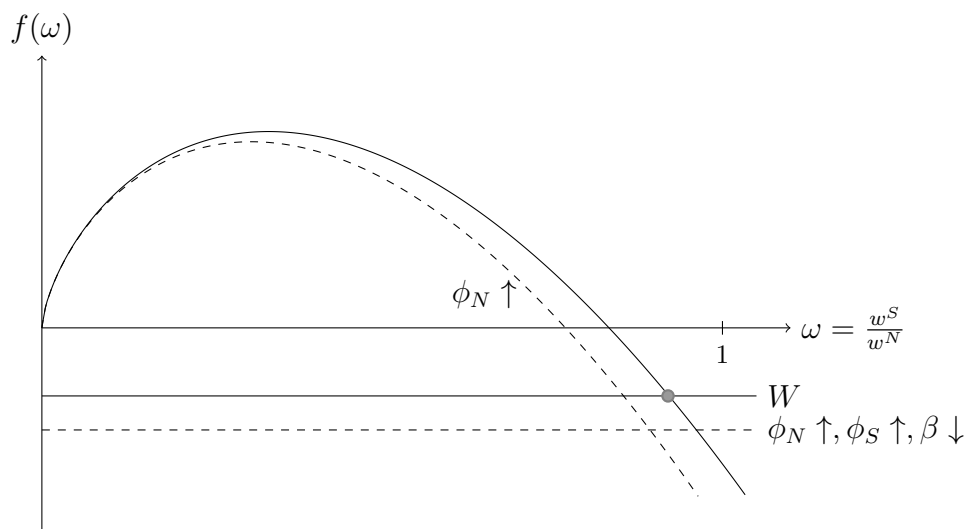

Figure A.5: Relative wage in the narrow-gap case.

balanced growth path effects can be derived analytically, numerical analysis shows that the remaining effects of changes in IPRs and research efficiency are qualitatively similar to the wide-gap case.

Appendix B. The Model without southern innovation

We turn now to a short description of the model for the case in which condition (11) is not satisfied such that southern research employment ℓ_R is zero or negative in the general model. As research labor cannot be negative, we set it to zero for both cases which restricts southern activity to the imitation of the North and production. In this case, $\ell_R = \ell_{C_S} = \ell_P = 0$.

The only R&D functions are (4a) for northern innovation and (5a) for southern imitation. Likewise, the no-arbitrage conditions for southern innovation and imitation of the South drop out. The labor market clearing condition for the South becomes $\ell = \ell_{C_N} + \ell_Y = \frac{a\phi_N \iota_N}{N^\theta}\dot{n}_{C_N} + n_{C_N}\bar{x}_{C_N}L$. Employment in the imitation sector ℓ_{C_N} is still given by (14), but the imitation rate in that equation is now different. Combining (10c) with the variety share ξ_R^* obtained from dividing the northern R&D function by N, using $\xi_{C_N} = \iota_N \xi_R^*/g$ and substituting for ℓ_R^* from (13) we can solve for $n_{C_N}\bar{x}_{C_N}$. To solve for the imitation rate we substitute $n_{C_N}\bar{x}_{C_N}$ and (14) in the above labor-market clearing condition.[19] The resulting quadratic equations for wide- and narrow-gap case have each only one positive solution which is given by:

$$\iota_N = \frac{\ell}{\ell^*}\frac{g^2}{2\Lambda_1 d\phi_N}\left(1 + \sqrt{1 + \frac{4\Lambda_1 d\phi_N}{g^2}\frac{\ell^*}{\ell}}\right), \qquad \omega \leq \alpha \qquad (B.1)$$

$$\iota_N = \frac{\frac{\ell}{\ell^*}g - \Lambda_3\sqrt{(\frac{\ell}{\ell^*}g - \Lambda_3)^2 + 4\frac{\ell}{\ell^*}g\Lambda_1(d\phi_N(1-\alpha) + \alpha^{1-\varepsilon})}}{2(d\phi_N(1-\alpha) + \alpha^{1-\varepsilon})}, \qquad \omega \geq \alpha \qquad (B.1')$$

in which $\Lambda_3 = \alpha^{1-\varepsilon}(\rho + \theta g)$. The imitation rate is increasing in the relative size of the South ℓ/ℓ^* and decreasing in the level of IPR protection ϕ_N. The relative wage is calculated as

$$\omega = \left(\frac{\rho + \theta g + \iota_N}{\rho + \theta g}\frac{g}{d\phi_N \iota_N}\right)^{\frac{1}{\varepsilon}}, \qquad \omega \leq \alpha \qquad (B.2)$$

$$\omega = \frac{g(\rho + \theta g + \iota_N)\alpha^{1-\varepsilon}}{(1-\alpha)(\rho + \theta g)d\phi_N \iota_N + g(\rho + \theta g + \iota_N)\alpha^{1-\varepsilon}}, \qquad \omega \geq \alpha. \qquad (B.2')$$

Like in the case with southern innovation, the relative wage between South and North is decreasing in the strength of IPR protection for northern goods. However, compared to the case in which southern innovation is possible, the imitation rate ι_N can never be zero, because

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[19]For the narrow-gap case, we additionally divide (10a) by (10c) to be able to substitute for the relative wage ω.

imitation and the production of imitated goods constitute the only southern activities. From this fact and from (B.2′) follows that $\omega < 1$ for all parameter values. Consequently, the South can never catch up to the North in wages in the no-innovation case.[20] Finally, southern asset holdings and consumption expenditures change with the cease of innovation in the South to $A = \xi_{C_N} d\phi_N wa N^{1-\theta} \iota_N$ and $e = \left(1 + (\rho + g_L)\frac{\xi_{C_N}}{\ell} d\phi_N a\iota_N N^{1-\theta}\right) w$, and the price index reduces to $P = N^{\frac{1}{1-\varepsilon}} [\xi_R^*(p_R^*)^{1-\varepsilon} + (1 - \xi_R^*)(p_{C_N})^{1-\varepsilon}]^{1/(1-\varepsilon)}$.

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[20]If innovation is possible in the South, wages in the two regions can equalize if the southern research sector catches up in efficiency. Setting $\omega = 1$ in (16′) we obtain the parameter combination under which wages are equal: $\Delta_1(\rho + \theta g)(1/\beta - 1) = g\eta^\star/\phi_S$. This condition says that the South can only catch up in wages if $\beta = 1$, i.e. if research in both regions is equally efficient. As northern products are not subject to imitation any longer in that case, equal wages require perfect IPR protection of southern innovations. This can be achieved by letting $\phi_S \to \infty$. Similarly $\beta = 1$ and $\eta^\star = 0$ lead to $\omega = 1$.

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